

SUPERVISED FULLY POLARIMETRIC CLASSIFICATION OF THE BLACK FOREST TEST SITE: FROM MAESTRO1 TO MAC EUROPE

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1. INTRODUCTION

We present a study on the performance of a supervised fully polarimetric maximum likelihood classifier for SAR data when applied to a specific classification context: forest classification based on age classes and in the presence of a sloping terrain.

For the experimental part of the study we use the polarimetric AIRSAR data at P, L, and C band, acquired over the German Black Forest near Freiburg in the frame of the 1989 MAESTRO-1 campaign and the 1991 MAC Europe campaign. MAESTRO-1 was an ESA/JRC sponsored campaign, and MAC Europe (Multi-sensor Aircraft Campaign) was organized by NASA; in both cases the multi-frequency polarimetric JPL-AIRSAR radar was flown over a number of European test sites.

The study is structured as follows. At first we investigate the general characteristics of the classifier and the dependencies from some parameters, like frequency bands, feature vector, calibration, using test areas lying on a flat terrain. Once we have determined the optimal conditions for the classifier performance, we then move on to the study of the slope effect. The bulk of this work is performed using the Maestro1 data set.

Next we consider the classifier performance with the MAC Europe data. The study here is divided into two stages: first we repeat some of the tests done on the Maestro data, to highlight the improvements due to the new processing scheme that delivers 16 look data. Second we experiment with multi images classification with two goals: to assess the possibility of using a training set measured from one image to classify areas in different images; to classify areas on critical slopes using different viewing angles.

In this summary paper we will list the main points of the study and highlight only some of the results obtained so far.

2. CLASSIFIER PRINCIPLES

The principles of the fully polarimetric maximum likelihood classifier are described in [Kong et al. 1987]. Suffice here only to say that the discriminant function, in the form of a minimum distance, is given by:

$$d_m(\mathbf{x}) = \mathbf{x}^* \cdot \mathbf{C}_m^{-1} \cdot \mathbf{x} + \ln |\mathbf{C}_m|, \quad (1)$$

where $\mathbf{x} = [HH \ HV \ VV]^T$ is the complex feature vector for the unknown pixel and \mathbf{C}_m is the spatially averaged covariance matrix of the training class.

3. GENERAL CLASSIFIER CHARACTERIZATION

3.1 Methodology

For the study of the classifier performance, we define training and test sets using the ground data collected during the Maestro1 campaign [Churchill 1989]; the forest is

segmented into stands characterized by the mean tree age. The tree ages have been grouped into four main classes: young trees (10–30 years), mature trees (30–70 years), adult trees (70–110), old trees (> 110 years). The training and test areas are taken on a flat terrain, to filter out from this analysis the influence of slope.

At this level of the study we then investigate the following points (see also [De Grandi et al. 1992]):

- characterization of the training sets through their covariance matrices
- classification performance as a function of the frequency bands
- dependency from the off diagonal terms of the covariance matrix
- dependency from polarimetric calibration
- relative weight of the feature vector elements in the discriminant function
- performance in the case of a one channel and a two channels feature vector

3.2 Results and discussion

As an example we report in table I the results of the classification of 3 forest age classes, an urban area and an arable field at P, L and C bands.

Table I – Confusion Matrix for 3 Forest Age Classes, an Arable Field and an Urban Area; Maestro1 Freiburg Data Set at P-, L- and C Bands

	P band					L band					C band				
	urban	arable	age1	age2	age4	urban	arable	age1	age2	age4	urban	arable	age1	age2	age4
urban	27.8	0.0	15.7	10.1	28.4	16.3	0.0	15.4	19.9	11.4	0.0	4.6	9.5	9.2	2.6
arable	0.0	100.	0.0	0.0	0.0	0.0	75.7	0.0	0.0	0.0	0.0	87.0	1.9	1.9	9.3
age1	0.0	0.0	92.7	4.9	2.4	0.0	0.0	75.6	17.1	7.3	0.0	14.6	34.2	22.0	29.3
age2	0.8	0.0	16.5	63.9	18.8	0.0	0.0	36.1	51.9	12.0	0.0	5.3	21.1	42.9	30.1
age4	3.1	0.0	4.0	30.9	61.8	0.0	0.0	49.7	28.3	21.9	0.0	7.5	19.7	26.1	46.8

Given the classification parameters of our test case, P band appears to be the most suitable for forest discrimination.

4. SLOPE EFFECT

4.1 Methodology

The Maestro1 Freiburg data set has been georeferenced [De Groof et al. 1991] and it is, therefore, possible to attach to each pixel in the image space the corresponding coordinates in the map space, and additional layers of information, such as the local incidence angle, and the slope. This processing step has then allowed us to divide each polygon representing an age class into sets of pixels having a given slope angle. In particular we defined 6 slope classes with angular spacing of 5 degrees. This spacing was chosen from considerations on the variance of the powers of the 3 polarimetric channels.

4.2 Discussion

The test set for 3 age classes exhibits high between groups variance when the 6 slope classes are considered and the confusion in the classification is therefore relevant. A

possible correction to the slope influence could be to drive the classifier with the knowledge of the slope angle for each pixel; in other words, the classifier could be switched among a number of different training sets, according to the slope angle of the pixel to be classified. Unfortunately this method works only for certain slope classes; indeed for positive slope angles greater than 10 degrees, the class separation is also affected, and therefore the classification accuracy is degraded even if a proper training set is taken into account. This can be seen for instance calculating the distance between 2 age classes and the 6 slope classes.

5. MAC EUROPE DATA

5.1 Methodology

The MAC Europe data have been processed with a new correlator and one of the available products is a 16 look data set. Moreover for the Freiburg test site we have at disposal a number of flights paths, both in the same direction and at orthogonal directions. This paves the way to an interesting experiment in multi image classification. First and essential step for this purpose is an accurate radiometric and polarimetric calibration of the data sets, and their co registration. By the time of writing of this summary this processing step is under way.

The plans are to explore the possibility of classifying multiple scenes using a training set measured on one scene, and to exploit the different viewing angles to resolve the confusion in forest age classification introduced by the terrain slope.

5.2 Preliminary results

Classification based on the same training set used in the test case with the Maestro data reported in section 3.2 has been performed on the Mac Europe data set with scene identifier cm3207. The results are reported in table II. The classification accuracy is significantly improved at P band with respect to the Maestro1 case.

**Table II – Confusion Matrix for 3 Forest Age Classes and an Arable Field;
MAC Europe Freiburg Data Set at P-, L- and C Bands**

	P band				L band				C band			
	arable	age1	age2	age4	arable	age1	age2	age4	arable	age1	age2	age4
arable	96.69	1.24	0.00	0.00	93.80	2.89	0.00	0.41	92.15	3.72	0.41	2.07
age1	0.00	92.86	3.57	3.57	7.14	64.29	25.00	3.57	21.43	57.14	17.86	3.57
age2	0.00	9.90	86.46	3.65	0.00	38.02	54.69	7.29	25.52	7.81	42.19	24.48
age4	0.00	1.06	8.46	90.48	0.00	56.34	28.85	14.80	34.74	14.50	13.29	37.46

6. REFERENCES

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